Radio Source Calibration Program (RASCAL)—Phase I: Antenna Gain Calibration

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A new program for measuring antenna gain of the large DSN antenna is described. The gain measurement procedure is outlined. Improvements over past techniques have resulted in better knowledge of Gain Standard Horn calibrations, in more compact procedure, and in changes in the precision comparison attenuator. The gain accuracy goal of the primary station is ± 0.05 dB, 1 σ.

I. Introduction

JPL has used tracking of well-known radio sources as a means of measuring the aperture efficiency of its large DSN antennas for the past several years. Recently, a technique to establish a firmer foundation for these measurements has been undertaken. This new technique employs a horn antenna as a primary gain standard. (This gain standard is presently being subjected to an absolute gain calibration in cooperation with the National Bureau of Standards.)

The first phase involves using the Moon-based ALSEP (*Apollo* Lunar Surface Experiments Package) as a far-field beacon to transfer the horn calibration to the 26-m-diameter antenna at DSS 13, Goldstone. The second phase uses the 26-m antenna to precisely measure the absolute flux density of Cygnus A. Once the radio source has been "calibrated" by the primary station, the resulting value can be used by any secondary station to measure its antenna efficiency. The primary station effort has been given the acronym RASCAL for Radio Source Calibration.

II. Functional Description

A block diagram is shown in Fig. 1. Conceptually, the procedure in obtaining a single gain data point is:

(1) Boresight the 26-m antenna (the beam of the Gain Standard Horn (GSH) is parallel to the 26-m antenna).

(2) Phase-lock the receiver to the ALSEP carrier and note the automatic gain control (AGC) voltage.

(3) Phase-lock the receiver to the test transmitter (50 kHz above ALSEP) and adjust the test transmitter signal to achieve the same AGC noted in Step 2 using the RF attenuators.

(4) Switch to the GSH, again phase-lock the receiver to the ALSEP carrier and note the AGC voltage.

(5) Again, phase-lock the receiver to the test transmitter and, using the RF attenuators, adjust the signal to achieve the same AGC noted in Step 4.

The gain of the 26-m antenna is equal to the gain of the GSH, plus the attenuation difference between Steps 3 and 5, less the differential waveguide loss between antennas:

$$G_{26} = G_{GSH} + \Delta\alpha - \alpha_{WG} \tag{1}$$

Figure 2 shows the Gain Standard Horn mounted on the 26-m antenna at DSS 13.

III. Improvements in Absolute Gain Calibration

An important improvement since the antenna gain calibration of Ref. 1 has been the improved absolute calibration of the Gain Standard Horn (Ref. 2). This subject will be covered in detail in a separate article. Briefly, it is expected that the old calibration uncertainty of ± 0.13 dB ($1\,\sigma$) will be reduced to approximately ± 0.033 dB ($1\,\sigma$).

In the test of Ref. 1 the RF attenuator used was an S-band rotary vane attenuator. While this is an excellent laboratory tool, its use for this application showed several problem areas. The device demonstrated a position sensitivity. A temporary remote drive readout mechanism was necessary. Finally, the field use of this precise laboratory device was felt to be undesirable. For these reasons, the rotary vane device has been replaced with a fixed switchable step attenuator plus a series vernier attenuator. The attenuation of the step attenuator was adjusted during fabrication to the expected gain difference between the large paraboloid and the Standard Horn, nominally 31 dB.

The vernier attenuator is a PIN diode modulator used in a duty-cycle-switching mode, i.e., the modulator is biased on and the average RF attenuation is increased by turning it off with pulses at a 4-kHz rate. The width of the pulses can be digitally adjusted so that the RF duty cycle and, hence, the average RF power correspondingly changes. The device is a modified form of that described in Ref. 3. These attenuators will be discussed in detail in a later article.

IV. Goal

The goal of the first phase of RASCAL is to determine the absolute antenna gain of the primary station antenna at DSS 13 to an accuracy of ± 0.05 dB, $1\,\sigma$. The effort will be a continuous one since improvements are scheduled to be made in the antenna, and the RASCAL program will be used to evaluate these improvements.

References

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2. Ludwig, A., Hardy, J., and Norman, R., "Gain Calibrations of a Horn Antenna Using Pattern Integration" (to be published).

3. Shallbetter, A. C., "Programmable Frequency Divider and Pulse Generator for Receiver AGC Calibrations," in *The Deep Space Network*, Space Programs Summary 37-56, Vol. II, pp. 134–139. Jet Propulsion Laboratory, Pasadena, Calif., Mar. 31, 1969.

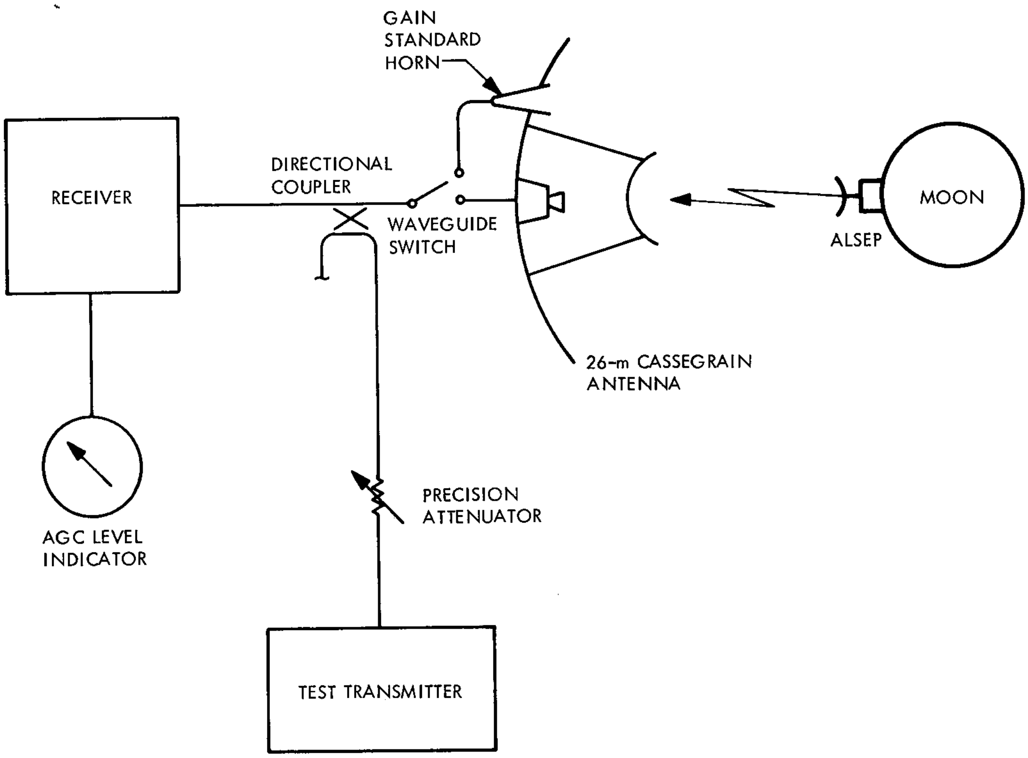

Fig. 1. Gain block diagram

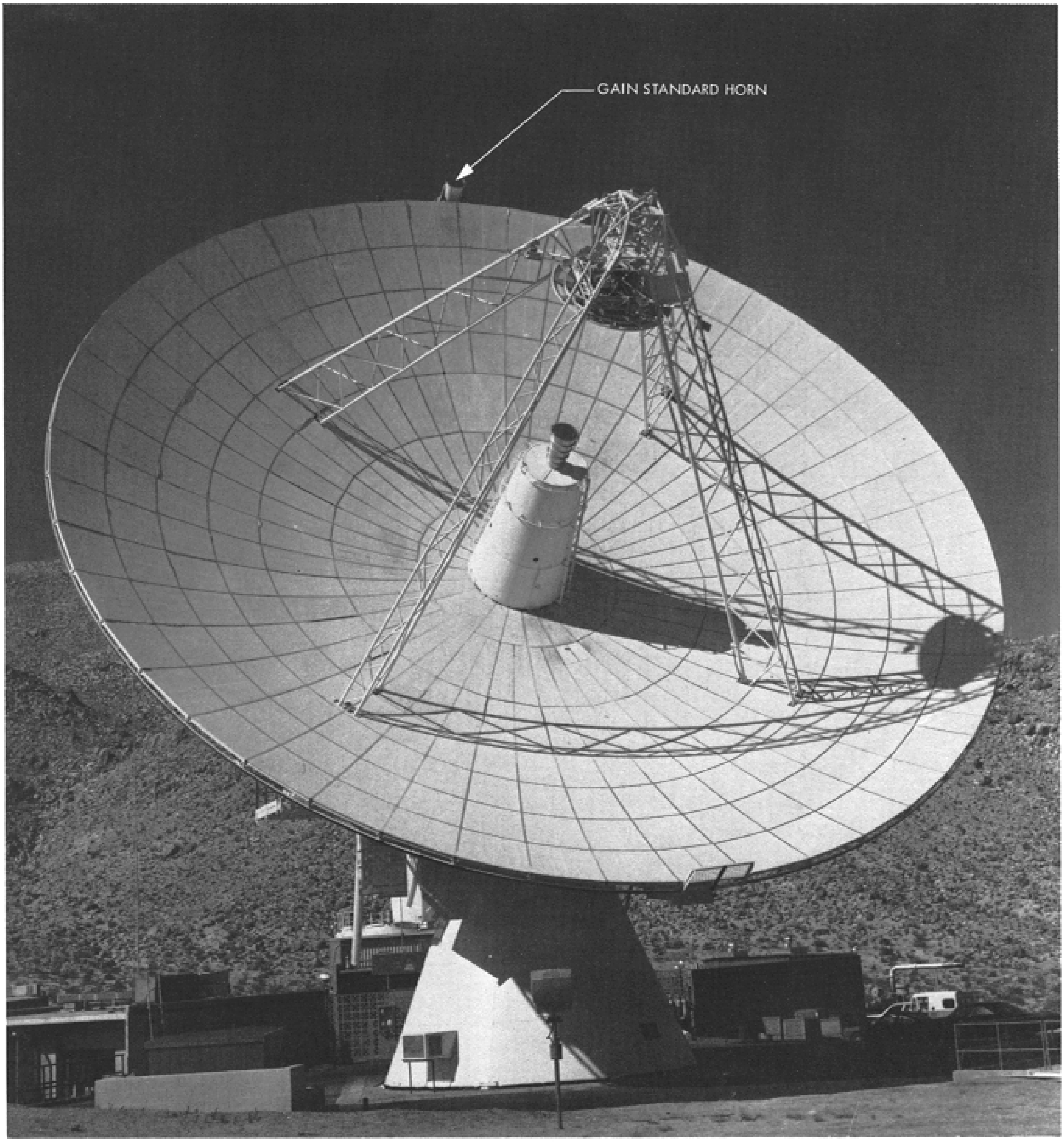

Fig. 2. DSS 13 26-m antenna with mounted Gain Standard Horn